Appendix C

Moisture Logging Field Report, Borehole 41-09-39

Apparent Neutron Moisture Survey Log

Of Borehole 41-09-39

Technical Guidance Provided by:

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1.0 INTRODUCTION AND PURPOSE

MACTEC-ERS requested a neutron-moisture survey of SX Tank Farm borehole, 41-09-39. Work Order number E62018.

At the request of MACTEC-ERS, the log survey data acquired and presented in this report is qualitative and provides a relative indication of the variations of formation moisture content as a function of depth in the borehole. Copies of the field notes, graphical representation of the survey data, and calibration certificate are included in this report.

The logging detector was calibrated in six borehole calibration models designed for vadose formations and steel cased boreholes.

2.0 EQUIPMENT DESCRIPTION

The neutron-moisture borehole instrumentation is a zero-spacing moisture gauge manufactured by Campbell-Pacific which has been adapted for use on the Radionuclide Logging System (RLS). The detector information and operating specifications are given in Table 1.

Table 1: Neutron-Moisture Borehole Detector Specifications

Neutron-Moisture Detector	
Rust-NW ID =	RLSM3.1
Model no. =	CPN - 503
Serial no. =	H38092510
Neutron source =	Chemical (AmBe)
Source size =	50 mCi
Detector type =	^3He
Detector size =	1" x 4" (4 atm)
Neutron sensitivity =	Thermal neutrons
MCA =	512 channels

The detector and probe electronics in the neutron-moisture sonde were improved December, 1996. The improvement objective was to increase the temperature operating range by reducing the detector and electronics sensitivity to temperatures above 100° F.

The neutron-moisture probe improvements were accomplished by upgrading the electronics and replacing the BF_3 detector with a ^3He detector. The ^3He detectors are sensitive to gamma-ray activity. To reduce the sensitivity to high gamma-ray flux the manufacturer set the lower-level discriminator above the gamma-ray signal responses. During the modification a hardened connector between the neutron probe and cross-over sub-assembly was installed to reduce the risk of potentially loosing the detector in a borehole.

The detector calibration and in situ survey are performed with the sonde centered in the borehole. Centering the detector in the borehole eliminates non-repeatable response surveys caused by non-uniform moisture distribution around the borehole axis. Instrument response studies with the detector side-walled and centered in the calibration models demonstrated that no loss of resolution occurs. (Randall et al. 1995)

The detector and electronics contained in probe RLSM1.1 and RLSM3.0 were both demonstrated to be temperature sensitive when a survey of borehole 41-12-01 was performed (Aug 1996). The repeatability of the detector response degraded as the temperature of the probe assembly increased. The electronics and detector assembly of two CPN neutron-moisture probes have been replaced with an improved version.

3.0 NEUTRON-MOISTURE RESPONSE IN BOREHOLE CALIBRATION MODELS

Borehole calibration measurements for RLSM3.1 were taken in six calibration models containing two casing sizes and three moisture volumes. Construction and assay contents of the Moisture Calibration Models are described in Engelman et al. (1995). The assigned moisture content of each model is given in Table 2.

Table 2: Moisture Calibration Model Summary

Model ID	Casing Size (in)	Hydrogen Index (VF-%)
F: 6", 5%	6	5.0
E: 6", 12%	6	11.7
G: 6", 20%	6	19.8
A: 8", 5%	8	5.0
C: 8", 12%	8	11.9
B: 8", 20%	8	19.7
D: 8", 40%	8	5.3 (top) 40.9 (mid 18") 5.1 (bot)
Model size: Height (inside) 1.9 m (75 in.) Diameter (inside) 1.5 m (59.5 in.)		

The logging probe was centered in the boreholes with the mid-point between the neutron source and ^3He detector (scribe mark on probe housing) positioned 3.0 ft from the top cover-plate of each calibration model. Ten measurements of 30 seconds (Real Time) were acquired in each model. The reported count rate is dead-time corrected by the electronics modules, the maximum dead-time was 1.6%. The counting uncertainty of each 30 second measurement at 150 cps is 1.5%. The neutron-moisture detector (RLSM3.1) response in each model is presented in Table 3.

Table 3: RLSM3.1 Response in the Moisture Calibration Models

Model ID RLSM3.1 Detector Response (cps) January 14, 1997					
6", 5%	6", 11.7%	6", 19.8%	8", 5%	8", 11.9%	8", 19.7%
189	276	357	149	210	258
190	281	348	149	209	251
192	282	354	148	209	254
185	273	348	153	208	251
191	277	353	146	206	252
193	278	353	148	204	259
191	274	351	146	212	252
188	279	352	150	205	257
182	279	347	150	206	253
189	276	353	145	210	255
avg=189	avg=278	avg=351	avg=148	avg=208	avg=254

Note that the detector responses vary with borehole size, 6-in and 8-in. Also, the outside diameter of nominal 6-in casing is 6-5/8 while the outside diameter of borehole 41-09-39 is 7-in. This difference in outside diameter is in addition to the difference in casing thickness between the calibration model and borehole survey. A correction factor for casing thickness has been determined. However, a correction for different casing diameters has not been determined. It is expected that a nominal correction for hole size is necessary.

The basic calibration function relating detector response (count rate) to formation moisture content (volume fraction, pct) is detailed in Randall et al. (1996) and Randall et al. (1995). The function form is:

$$MOIST_{vf} = a \cdot CPS^{b} \qquad (1)$$

Where:
MOIST is the calibrated volume fraction of water in vf units,
a,b are the fit coefficients, and
CPS observed instrument count rate (counts per second), dead-time corrected.

The calibration coefficients for RLSM3.1 (Jan 14, 1997) are presented on the Certificate of Calibration (attached). The calibration coefficients for RLSM3.1 in a 6" borehole are:

$a = 45.04 * 10^{-6}$
$b = 2.217$

4.0 NEUTRON-MOISTURE SURVEY OF BOREHOLE 41-09-39

The neutron-moisture survey of 41-09-39 using detector RLSM3.1 was acquired on January 22, 1997. The Borehole Survey Data Sheet (completed during field survey) is attached. The borehole configuration, chronology of field activities, and survey specifications are shown in Table 4.

The sample time interval was changed from 30 sec to 25 sec to speed the logging. This was allowed by the larger count rates provided by the new detector.

Two overlay/repeat sections were made to test the temperature sensitivity of the system. No temperature or gamma ray sensitivity was observed.

Table 4: Borehole 41-09-39 Configuration and Survey Specifications

Borehole 41-09-39 Configuration and RLGM3.1 Survey Specifications	
Borehole Size =	7" OD
Casing Thickness =	0.5"
Casing Type =	carbon steel
Depth Datum Reference =	Ground Level
Depth Increment =	0.5 ft
Chronology	
9:30	TF operator provide entry into SX Tank Farm.
10:00	Apply electrical power to probe and amplifier electronics.
10:40	Beginning logging at 130 ft. (probe centered in borehole)
1:40	Complete logging at 0 ft.
2:30	TF exit survey

Depth Range (ft)	Log Mode	Data File#
130 - 110	MSA 30s	000-039
110 - 100	MSA 25s	040-060
110 - 60	MSA 25s	060-161
80 - 0	MSA 25s	162-322

5.0 SUMMARY

The neutron-moisture survey of borehole 41-09-39 was performed with the detector centered in the borehole and repeat intervals in both high temperature and high gamma-ray flux zones show excellent repeatability. The borehole probe does not appear to be sensitive to high temperature environments or high gamma-ray flux. Correction for the 0.5-in thick casing must be performed when computing the apparent formation moisture content. The raw neutron-moisture survey data with repeat intervals are presented in Figure 1.

6.0 REFERENCES

Meisner J.E., R.R. Randall, and R.K. Price, 1995, *Vadose Zone Moisture Measurement Through Steel Casing Evaluation*, WHC-SD-EN-TI-304 revision 0, Westinghouse Hanford Company, Richland, Washington

Randall, R.R., J.E. Meisner, and R.K. Price, 1996, *Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibrations*, WHC-SD-EN-TI-306 revision 0, Westinghouse Hanford Company, Richland, Washington

Engelman, R.E., R.E. Lewis, D.C. Stromswold, and J.R. Hearst, 1995, *Calibration Models For Measuring Moisture In Unsaturated Formations by Neutron Logging*, PNL-10801, Pacific Northwest National Laboratory, Richland, Washington

Reviewed and Modified by: James E Meisner 2/10/97

J. E. Meisner, Principal Engineer
Rust Federal Services, Inc.
Northwest Operations

Date

Neutron Moisture Borehole Survey

Location : SX Tank Farm, 200 Area   Log Date   Jan. 22, 1997

Borehole: 41-09-39

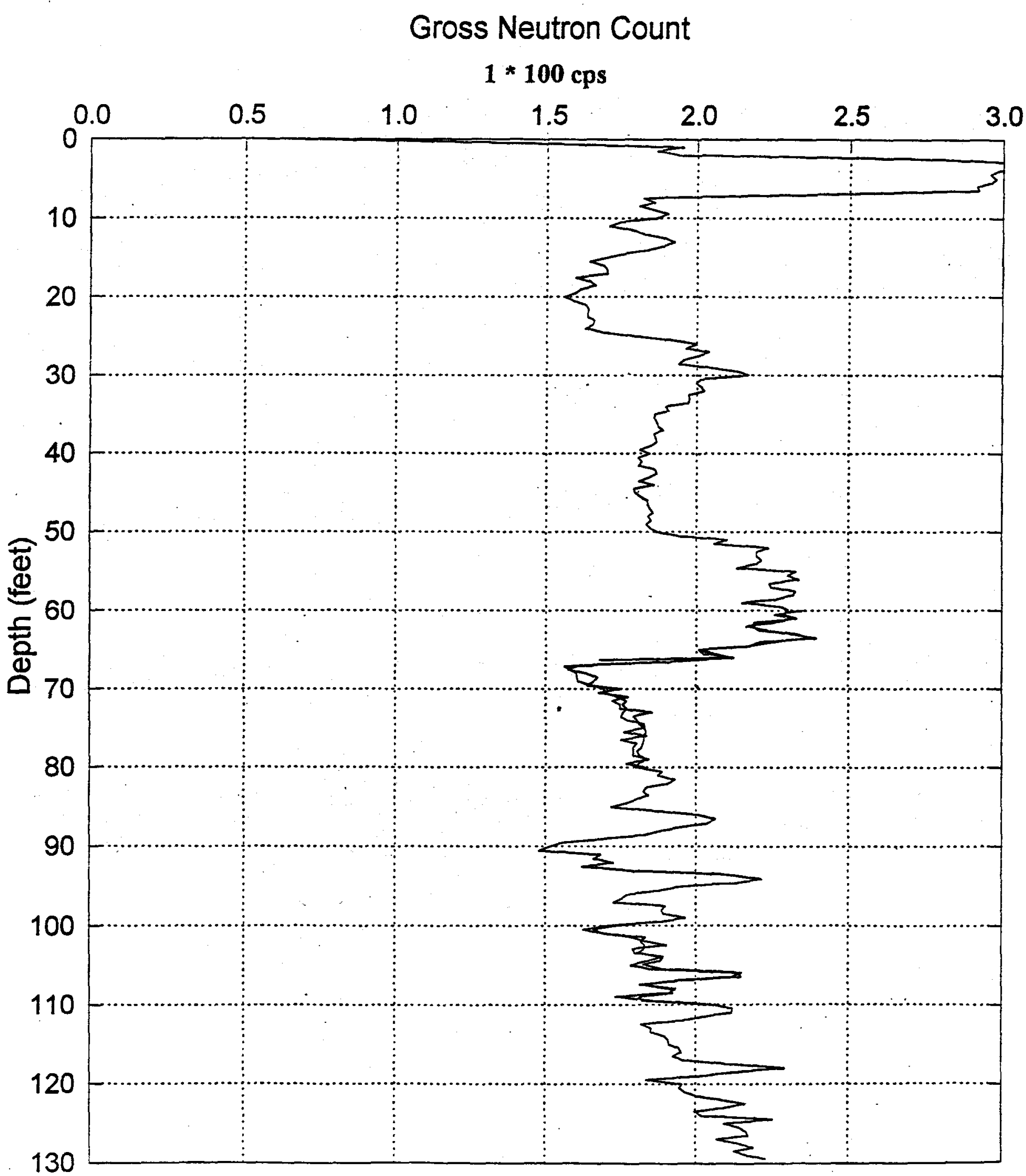


FIG. 1

Certificate of Calibration
RLSM3.1
January 30, 1997

Data was taken at the Pasco models on Jan 14, 1997. RLSM3.1 is the designated moisture tool M3 in the version .1, thus the M3.1. The change from M3.0 is caused by the addition of new detector and electronics from the M3.0 version.

Six models were used for moisture calibration, 3 for 6"casing and 3 for 8" casing. Ten spectra were recorded for each model in order to perform statistical analysis. The observed statistical variation agreed with the theoretically predicted variation, refer to the file stats.WK4 for this analysis.

The coefficient analysis is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is linear and defined by:

$$V = a \cdot CR^{\alpha}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s).

6" casing	8" casing
a = .00004504	**a = .00001412**
α = 2.217	**α = 2.555**

Digital files condensed as MST1.zip. This compressed file contains:

- Calibration raw data
- MathCad data analysis files
- Spreadsheet data formatting
- Cover letter noting results and/or recommendations
- Log data collection reporting files

Signature: Kenneth Randall (signature)

Date: 1-30-97

Company:

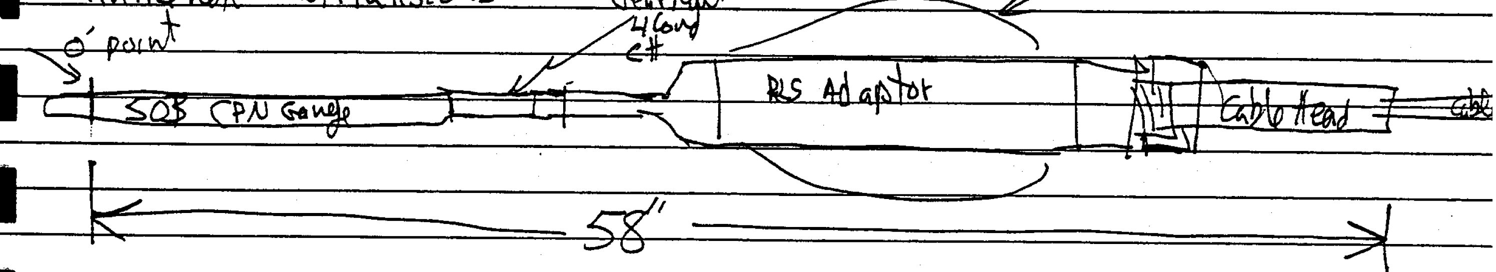
Three Rivers Scientific

RLSm ~~3.0~~ 3.1 Jun Calibration 1/14/97

J. Meisner
J. Kiesler @ Lampson Building #3 in Pasco

Amp - 672 Settings
- Fine = 0.778 Course = 50 gain
- + input, TC = 2us
- PZ = manual
- BLR = Auto

Instrument Dimensions :



Instrument Placed 3.0 feet into each model; thus the top of Cable Head sticks up 22"
Outside Temp ≈ 20°F
Clear day
Inside Temp of Bldg ≈ 50°F

File	Sample Time	Model	CPS, gross
msc11000 - 2	100 Sec	6", 20%	
msc11003-11	30 Sec	6", 20%	352
msc11012-21	30 Sec	8", 20%	252
msc11022-31	30 Sec	6", 12%	274
msc11032-41	30 Sec	8", 12%	210
msc11042-51	30 Sec	6", 5%	189
msc11052-61	30 Sec	8", 5%	144
msc1KAB	100 Sec	std	735
msc11CAA	100 Sec	std	717